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EXPERIMENTS WITH DDT AGAINST INSECTS ATTACKING GUAYULE

By V. E. Romney, T. P. Cassidy, and G. T. York,
Division of Forest Insect Investigations

Guayule (Parthenium argentatum Gray) is a shrub being grown under field conditions as a war measure for its rubber content, and under greenhouse conditions for experimental purposes. A number of pests attack guayule under field and greenhouse conditions, such as Lygus bugs, red spiders, whiteflies, mealybugs, thrips, and aphids. This paper reports results from tests conducted at Salinas, Calif., during the period January 1944 to February 1945 to determine the effect of DDT (1-trichloro-2,2-bis(p-chlorophenyl)ethane) on these pests.

Formulations

The DDT was applied both as a dust and as a spray. Dusts were made by dissolving 1 part of DDT (technical) in 2½ parts of acetone and using this solution to impregnate pyrophyllite, the amount of carrier depending upon the percentage of DDT required in the dust. The pyrophyllite wetted with the DDT-acetone solution was spread over paper and allowed to dry for 24 hours and then ground in a ball mill for 2 to 3 hours.

For sprays the DDT was used in the form of an emulsion. An emulsion concentrate was made up according to the following formula 1/ (figures in parts by weight): DDT 15, acetone 30, methylcyclohexanol 15, sulfonated vegetable oil 36, and ammonia 4. Addition of ammonia was later found to decrease stability of the concentrate and add nothing to toxicity. The acetone and methylcyclohexanol were warmed together over a water bath, the DDT was dissolved in the warmed mixture, and then the sulfonated vegetable oil-ammonia mixture was added slowly with stirring. According to the manufacturer, the vegetable oil contained 75 percent of sulfonated castor oil. For use the concentrate was diluted, usually at the rate of 1 part to 50 parts of water to make a 0.3-percent DDT emulsion. In some tests a wetting agent was added to the water, and in others the amount of DDT varied.

1/ This is a modification of a formula given in Soap and Sanit. Chem. 19 (7): 103 (example 1). 1943.

Preliminary Cage Tests

For preliminary tests with DDT dusts the cylindrical cage illustrated in figure 1 2/ was used. The cage was made of 16-mesh screen wire and measured 3½ inches in diameter by 5½ inches tall. The base was a pint ice-cream carton which had been treated with hot paraffin to enable it to retain water. Nettleleaf goosefoot (Chenopodium murale L.) was used as a food plant in most tests. The dusts were applied with a samll plunger-type hand duster, by giving two puffs on opposite sides of each cage. Excess dust was blown by mouth from the floor of the cage after each treatment. Most of the tests with dusts were arranged as randomized blocks and replicated 10 times with 10 insects in each cage. The insects within the screen-wire cages were treated with DDT dusts in a frame building, then moved immediately into a screened insectary during January 1944 when maximum temperatures ranged from 65°to 75° F. and minimum temperatures from 35° to 41°.

Results from cage tests using 5-percent DDT dust against adults of Lygus hesperus Knight after 24 hours showed 90 percent dead, 8 percent down, and 2 percent normal, compared with 55 percent dead, 29 percent down, and 16 percent normal for the 2.5-percent DDT dust. After 48 hours the 2.5-percent DDT dust killed 94 percent and 6 percent were down, showing that this plant bug is highly susceptible to DDT.

Tests conducted with the western spotted cucumber beetle (Diabrotica undecimpunctata Mann.) showed that this insect is more susceptible than Lygus to the DDT dusts. The 2.5-percent dust killed 91 percent of the beetles after 24 hours, and after 48 hours all were dead, while none were dead in the checks.

Similar tests replicated seven times showed adults of the false chinch bug (Nysius ericae var. minutus Uhler) to be highly susceptible to 5-percent DDT dust after 24 hours, while in two replications larvae of the diamondback moth (Plutella maculipennis Curt.) were less susceptible, although all larvae were either dead or down on the bottom of the cage after 24 hours.

Aphids were less susceptible to DDT than the insects mentioned above, although kill was practically complete within 5 to 7 days after treatment. The effect of 5-percent DDT dust on the turnip aphid (Rhopalosiphum pseudobrassicae (Davis)) illustrates the effect of DDT on aphids. This species was found reproducing in the tips of Brassica

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2/ Designed by the senior author and Orin A. Hills in 1939.

sp. Infested tips were dusted with 5-percent DDT and then enclosed in cheesecloth. The treatments were replicated five times. After 3 days 65.1 percent of the aphids were dead or down, after 5 days 97.9 percent, and after 7 days 100 percent. In the checks from 1.3 to 6.3 percent were dead or down. During the experiment maximum temperatures averaged 65.4° F. and minimum temperatures 40.3°. Similar results with respect to time required to kill and general susceptibility were obtained with the green peach aphid (Myzus persicae (Sulz.)) and the pea aphid (Macrosiphum pisi Kltb.).

Field Experiments for Control of Lygus Bugs

Two experiments for control of Lygus hesperus on guayule were conducted under field conditions beginning in June. In experiment 1 DDT was applied as dusts and sprays, each in two concentrations, with 5 replications of each test. A 5 by 5 Latin-square arrangement was used with plots 40 feet square. The dusts were applied with rotary hand dusters. The sprays were applied with equipment illustrated in figure 2, which consisted of a paint gun and an air compressor (5), with a gasoline motor for power. An air pressure of 65-75 pounds per square inch was maintained. In the sprayed plots only 8 of the 16 rows in a plot were treated, but the dusts were applied to the entire plots. Six days after treatment counts were made with a sampling cage (Hills 2). The results, given in table 1, show 98 percent kill or higher from all treatments. These large reductions in Lygus numbers, effected by single applications of DDT, caused highly significant increases in the viability of guayule seed over that produced in the untreated check plots. The seed was harvested from six tagged plants near the center of each treated plot. These results are in agreement with those obtained by Hills (3) on sugar-beet seed.

Table 1.--Effect of DDT on Lygus hesperus populations under field conditions and the effect on the viability of guayule seed. Salinas, Calif., June 16 to July 20, 1944

Concentration of DDT	Dosage of mixture per acre	Mortality of adults and nymphs	Average germination of guayule seed 1/
Percent	Pounds	Percent	Percent
Dusts:			
2.5	33.9	98.0	34.4
5	33.1	99.6	32.4
Emulsions:	Gallons		
0.15	74.6	98.8	33.7
.3	74.6	99.6	29.8
Difference required for significance at 5-percent level.....			12.4

1/ Germination in untreated checks, 16.1 percent.

In experiment 2 about 3 acres composed of many small plots were sprayed with a 0.134-percent DDT emulsion at the rate of 76.5 gallons per acre. The spray was applied with a 10-nozzle power sprayer at 100 pounds pressure. Counts were made 4 days after treatment. Kill of adults and nymphs averaged 95.8 percent, which corroborates results from other tests showing the effectiveness of DDT against Lygus bugs.

Two plots of lima beans (65 by 104 feet) were treated with 5-percent DDT dust with a rotary hand duster at the rate of 40 pounds per acre on August 15. Counts made 2 weeks later with a sampling cage showed an average of 1.7 Lygus adults and no nymphs per foot of row in the treated plots, compared with 6.1 adults and 10.2 nymphs per foot in two untreated checks. There had apparently been some reinfestation by adults in the plots after treatment. No plant injury was noted.

Experiments for Control of Greenhouse Pests

Red spiders.--The problem of controlling mites and insects on guayule under greenhouse conditions has been of major concern. The shrub is a good host of the two-spotted mite (Tetranychus bimaculatus Harvey), as identified by E. A. McGregor. Control of the mite has been essential to the success of experimental work where plants remain in the greenhouse throughout a normal growing season or continuously for several years. Dusting sulfur has been recommended for red spider control, and it was used on guayule with fair success, but when it was applied to mariola (Parthenium incanum H.B.K.) or crosses of mariola with guayule under greenhouse conditions, it burned the leaves.

Weigel (7) reported poor results against Tetranychus spp. in several tests with DDT in aerosol form, spray suspensions, and dusts. However, in most cases he measured the effects after 48 hours, which is too soon for maximum results with red spiders. Steiner (6) reported that red spiders became more numerous on apple trees sprayed with DDT suspensions, and that the killing of certain predators allowed an increase of European red mites (Paratetranychus pilosus (C. and F.)) after treatment. Baker and Porter (1) also state that at dosages used against the codling moth (Carpocapsa pomonella (L.)) the DDT did not control orchard mites. These workers, among others, have contributed to the general impression that DDT is not very toxic to red spiders and that it has little chance of being used in their control. Data presented in this paper, however, show that red spiders are more difficult to control with DDT than are many forms, but that DDT is toxic to them and that control may be a matter of formulation and proper application.

In tests for red spider control the DDT emulsions were applied with a paint gun (fig. 2) with air pressure set at 40 to 50 pounds per square inch. Approximately the same amount of emulsion was applied for each treatment within an experiment, which was enough to wet the upper and lower leaf surfaces to the dripping point. The spraying was done outside the greenhouse, and as plants for each treatment were sprayed they were moved into position on a bench in the greenhouse. Tests with emulsions were arranged as randomized blocks with 3 to 8 replicates.

Five experiments were conducted during the period March 1944 to February 1945 to determine the effect of DDT emulsions and other recommended chemicals against Tetranychus bimaculatus. The results, which are given in table 2, were determined by examining both surfaces of 10 to 15 leaves taken at random from each plant, with the aid of a binocular microscope.

Table 2.--Effect of DDT and other materials on Tetranychus bimaculatus applied as sprays under greenhouse conditions on guayule

Spray treatment	Time between treatment and counts	Total mites and eggs in leaf samples	Total live mites larger than first instar	Kill of eggs and mites
	Days	Number	Number	Percent
Experiment 1, three replicates				
Checks, water, once	5	2,065	1,343	4.6
	12	951	678	6.3
DDT emulsion, 0.3 percent:				
Once	5	1,514	6	88.1
	12	945	14	92.7
Twice	5	1,209	5	99.3
Tartar emetic-glycerol:				
Once	5	1,741	253	66.1
	12	1,228	219	57.8
Twice	5	1,856	149	79.3
Experiment 2, eight replicates [1/]				
Checks, water	6	22,606	8,149	1.4
DDT emulsion:				
0.1 percent	6	13,072	269	89.8
0.3 percent	6	14,069	7	98.1
Experiment 3, seven replicates				
Checks, water	6	1,633	630	7.7
DDT emulsion, 0.3 percent	6	1,439	1	96.4
Experiment 4, five replicates				
Checks, water	9.5	2,545	791	4.7
DDT emulsion, 0.3 percent:				
Regular formula (in water)	9.5	1,106	21	89.2
In 0.01-percent Vatsol OT	9.5	1,023	11	91.6
In 1-percent Triton B-1956	9.5	1,038	6	93.6
DN-111, ½ lb. per 100 gal.	9.5	2,657	97	55.5
Triton B-1956, 2 percent	9.5	2,303	46	81.8

1/ On mariola plants.

Table 2.--(Continued)

Spray treatment	Time between treatment and counts	Total mites and eggs in leaf samples	Total live mites larger than first instar	Kill of eggs and mites
	Days	Number	Number	Percent
Experiment 5, six replicates				
Checks, water containing acetone 0.6 percent and Vatsol OT 0.01 percent	8	8,299	3,693	2.8
DDT emulsion, 0.3 percent:				
Regular formula	8	2,828	3	97.0
Less ammonia	8	2,500	6	95.9
Less DDT	8	4,659	2,013	13.6
Less methylcyclohexanol	8	2,527	8	96.6
Less sulfonated vegetable oil	8	4,103	1,573	30.1
Sulfonated vegetable oil in 0.01-percent Vatsol OT	8	5,433	2,040	17.1
DDT 0.3 percent with acetone in 0.01-percent Vatsol OT	8	4,240	2,227	16.5

In the first experiment 9 guayule plants containing these mites were sprayed with 0.3-percent DDT emulsion. Results on 3 of these plants were recorded after 5 days, and on 3 others after 12 days, while 3 plants were sprayed a second time on March 26 and the results recorded 5 days after the second treatment. The same arrangement was made for plants sprayed with tartar emetic-glycerol, which was used at the rate of 20 grams of tartar emetic and 100 ml. of glycerol per gallon of water, as suggested by Weigel and Johnson (8). Daily maximum temperatures averaged 89° F. and ranged from 78.5° to 95°; minimum temperatures averaged 66.9° and ranged from 61° to 76°. The high kill of mites and eggs after one application of DDT emulsion indicates a

residual effect on the newly hatched mites. Two applications almost eliminated the mite population. Most of the live mites found on these plants were newly hatched, and some of them were abnormally sluggish. The tartar emetic-glycerol spray was not nearly so effective as the DDT. Both sprays showed some ovicidal effect. Slight plant injury was caused by the tartar emetic, while none was noted on plants sprayed with DDT.

Experiment 2 shows very effective results with the 0.3-percent DDT emulsion as applied to mites on mariola plants and significantly less kill with the 0.1-percent emulsion. Experiment 3 corroborates the results of experiments 1 and 2 with respect to the effectiveness of 0.3-percent DDT emulsion. Again the number of live mites larger than first instar was remarkably low.

Experiment 4 was conducted to determine the comparative effectiveness of DN-111 (a dinitro-o-cyclohexylphenol salt), Triton B-1956 (a phthalic glyceryl aklyd resin), as suggested by Parker (4), and DDT emulsions, both the regular formula and with the addition of a wetting agent. Infested guayule plants were sprayed with approximately 100 ml. of each material used. Daily maximum temperatures averaged 82.4° F. and ranged from 77° to 92°; minimum temperatures averaged 59.5° and ranged from 58° to 62°. There was an obvious difference in results between the checks and the treatments. Statistical analysis showed the combined kill of mites and eggs sprayed with DN-111 to be significantly less than with the other treatments, owing to an apparent lack of ovicidal effect. When based on kill of mites, however, there was no statistical difference in effectiveness of the various treatments.

Experiment 5 was conducted from February 3 to 11, 1945, to evaluate the various components of the DDT emulsion used to control red spiders in 1944. One ingredient in this formula was deleted at a time and the remaining mixture was tested. The checks were sprayed with water containing 0.6 percent of acetone and 0.01 percent of Vatsol OT, since these ingredients were common to all treatments in this experiment. The amount of material sprayed on the six plants in each treatment ranged from 370 to 391 ml. After treatment the plants were maintained in a greenhouse section at 70° to 80° F. The data (experiment 5, table 2) show that the DDT is the principal toxic ingredient, and that neither ammonia nor methylcyclohexanol appreciably increases the toxicity. The sulfonated vegetable oil appears to be very important in combination with DDT, but alone it killed only a small percentage of eggs and mites. An emulsion of DDT with acetone and Vatsol OT alone is undesirable, since the DDT readily separates out upon dilution with water.

Some information relative to the rate of kill in experiment 5 was obtained by placing collars around each plant, as illustrated in figure 3. Dead mites were collected from the collars 48, 96, and 144 hours after treatment. Around the plants sprayed with the regular DDT formula 884 dead mites were collected after 48 hours, 670 after 96 hours, and 562 after 144 hours. During the first 48-hour period more than three-fourths of the dead mites on the collars were larger than first instars, but during the second period this condition was reversed, and during the third period 92.5 percent were newly hatched.

Samples from six lots of technical DDT from the same company were used in preparing 0.3-percent emulsions to determine whether or not the DDT in the various lots varied in toxicity to the two-spotted mite. Six guayule plants were sprayed with each emulsion. The regular formula was used with the addition of 0.01-percent Vatsol OT. Results from this experiment are given in table 3. Lot 6 was found to be significantly less toxic than the other five lots. These results were similar to those obtained in greenhouse control operations with the same lots of DDT when the wetting agent was used with the regular formula.

Table 3.--Toxicity of various lots of DDT to Tetranychus bimaculatus 8.5 days after spraying with 0.3-percent DDT emulsion

Lot	Average number per guayule leaf			Kill of mites and eggs 1/
	Dead mites and collapsed eggs	Live mites	Viable eggs	
				Percent
1	26.1	.59	.63	95.5
2	23.6	.45	.72	95.3
3	19.8	.65	.92	92.7
4	19.5	.22	.43	96.8
5	17.0	.67	.56	93.3
6	13.1	1.12	.78	87.3
Difference required for significance -percent level				4.9

1/ Plants sprayed with 0.6-percent acetone and 0.01-percent Vatsol OT were used as checks, and 3.5 percent of the mites and eggs were dead on the plants.

Mealybugs.--An experiment was begun on May 5 to determine the effectiveness of 0.3-percent DDT emulsion on the Mexican mealybug (Phenacoccus gossypii T. and C.). Five plants were sprayed with the DDT emulsion and five plants were sprayed with water as checks. Two treatments were replicated 5 times. Seven days after the plants were sprayed all mealybugs and egg masses were counted on the 10 plants in the experiment and on paper collars around the base of these plants. The survival after 7 days varied with the form of the insect. The immature stages were effectively controlled. Females without egg masses averaged 48.1 percent alive, and those with egg masses 77.4 percent. Males in cocoons averaged 22.1 percent alive. About half of the egg masses were at least partly destroyed by the treatment. Since the population consisted largely of immature stages, an

average of 87.2 percent control was effected for all stages. Seven days after spraying there were on the 5 treated plants 27 females without egg masses, 62 females with egg masses, 267 males in cocoons, and 1,135 of the immature stages; of this total 1,301 were dead and 191 were alive.

The residual effect of 0.3-percent DDT emulsion on nymphs hatching from recently deposited egg masses of Phenacoccus gossypii was tested by treatment of two plants on May 12. Seventeen days later mealybugs were counted on the treated and check plants and on the collars around the base of the plants. Most of the mealybugs had died soon after leaving the eggs, and only a few that had managed to get onto new growth had survived. The insect was found to be very susceptible to the residual effect of the DDT when in the first two instars, although the majority were killed while still in the first instar. The later instars showed greater resistance. Apparently two applications properly timed would eliminate an infestation of this species of mealybug.

Miscellaneous greenhouse pests.--Eighteen potted guayule plants became infested under green house conditions with Aleyrodes spiraeoides Q. and Trialeurodes vaporariorum (Westw.) (whiteflies), Myzus persicae (aphid), Tetranychus bimaculatus (mite), Frankliniella occidentalis trehernei Morg., Thrips tabaci Lind. (thrips), Empoasca arida DeL., (leafhopper), and spiders. Nine plants selected from the group at random were sprayed with 0.3-percent DDT emulsion on May 23. They were then covered with fine-mesh cheesecloth cages (fig. 3) and placed on a greenhouse bench. The other 9 plants were sprayed with water, also encaged with cheesecloth, and placed on another bench.

Fourteen days after treatment the cages were inspected by untying the tops and counting all forms which could be found in them, except mites. The insects were counted as they were removed from the cages. All species were taken from the check cages in various degrees of abundance, but not a single live specimen was found in the cages on the sprayed plants. Seventeen days after treatment 10 leaves collected at random from each of these plants were examined for insects under a binocular microscope. One whitefly pupa, which appeared to be alive, was found on the treated leaves and all other forms on them were dead, while many live insects and mites were found on the leaves from the check plants.

Control of Miscellaneous Pests with DDT

The field cricket (Gryllus assimilis (F.)) was found to infest greenhouses during the fall rainy season at Salinas. Infestations were often large, and controlled by dusting lightly with either 5- or 10-percent DDT in locations frequented by them. Crawling of the

crickets over the dusted surfaces was apparently lethal. A bait made with 1 part by weight of 10-percent DDT dust and 10 parts of commercially sweetened bran was also found to be effective against crickets. The combined treatment of dusting and baiting proved very effective.

Soil in ice-cream cartons dusted lightly with 5-percent DDT dust killed 72 percent of the sowbugs confined in them within 4 days and 94 percent within 7 days. Under field conditions dusting the soil with 5-percent DDT gave effective control of sowbugs after 10 days.

Barracks infested with the bedbug (Cimex lectularius L.) were sprayed with a 5-percent DDT-kerosene solution by use of the paint gun illustrated in figure 2, with air pressure set at 90 pounds. All cracks on the inside of the building and the wooden cots were sprayed. This treatment controlled the bedbugs.

The windows, ceilings, and walls of rooms sprayed lightly with a 2.5-percent DDT-kerosene solution were found to be lethal to houseflies (Musca domestica (L.)) and mosquitoes in the vicinity of Salinas for approximately 30 days, after which the effect dwindled until practically no effect was apparent after 60 days.

Frame houses in the vicinity of Salinas became heavily infested on the outside with several species of webbing spiders. One test showed a 2.5-percent DDT-kerosene solution to be very effective against them when applied with a paint gun at 90 pounds air pressure.

Summary

Preliminary cage tests showed that adults of Lygus hesperus Knight, the western spotted cucumber beetle (Diabrotica undecimpunctata Mann.), and the false chinch bug (Nysius ericae var. minutus Uhler), and larvae of the diamondback moth (Plutella maculipennis Curt.) were highly susceptible to DDT dusts. Aphids were susceptible to DDT dusts, but maximum kill did not occur until 5 to 7 days after treatment. Those tested included the turnip aphid (Rhopalosiphum pseudobrassicae (Davis)), the green peach aphid (Myzus persicae (Sulz.)), and the pea aphid (Macrosiphum pisi Kltb.).

Field tests showed Lygus hesperus to be very susceptible to dusts and emulsions containing DDT, and since dusts are more convenient to apply, they are recommended for control of this insect.

Experiments conducted under greenhouse conditions for control of the two-spotted mite (Tetranychus bimaculatus Harvey) showed that a 0.3-percent DDT emulsion was effective. This spray caused no damage to guayule, mariola, or related plants even after repeated

applications. Other recommended materials such as sulfur, tartar emetic-glycerol, DN-111 (a dinitro-o-cyclohexylphenol salt) and Triton B-1956 (a phthalic glyceryl alkyd resin) were less effective.

The susceptibility of the Mexican mealybug (Phenacoccus gossypii T. and C.) to 0.3-percent DDT emulsion was found to vary with the form. The immature stages were effectively controlled after 7 days, and females with egg masses were the most resistant. A residual effect is indicated, since leaves sprayed with this emulsion killed most small forms soon after hatching.

When guayule plants sprayed with 0.3-percent DDT emulsion were enclosed in cheesecloth cages, all insects, mites, and spiders were killed.

DDT dusts were effective against crickets and sowbugs when applied to their habitats. Kerosene solutions containing from 2.5 to 5 percent of DDT applied with a paint gun were very effective against bedbugs, houseflies, mosquitoes, and spiders.

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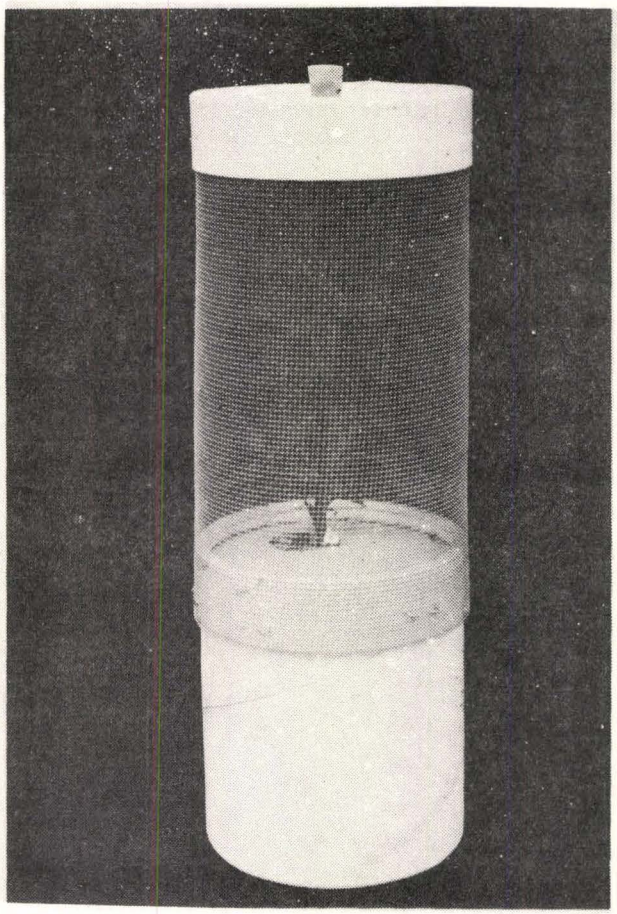

Figure 1.--Cage used for insect-toxicity tests with DDT dusts.

Figure 2.--Equipment used for spraying guayule with DDT emulsion: Left, paint gun being used to spray guayule; right, compressor with air hose attached.

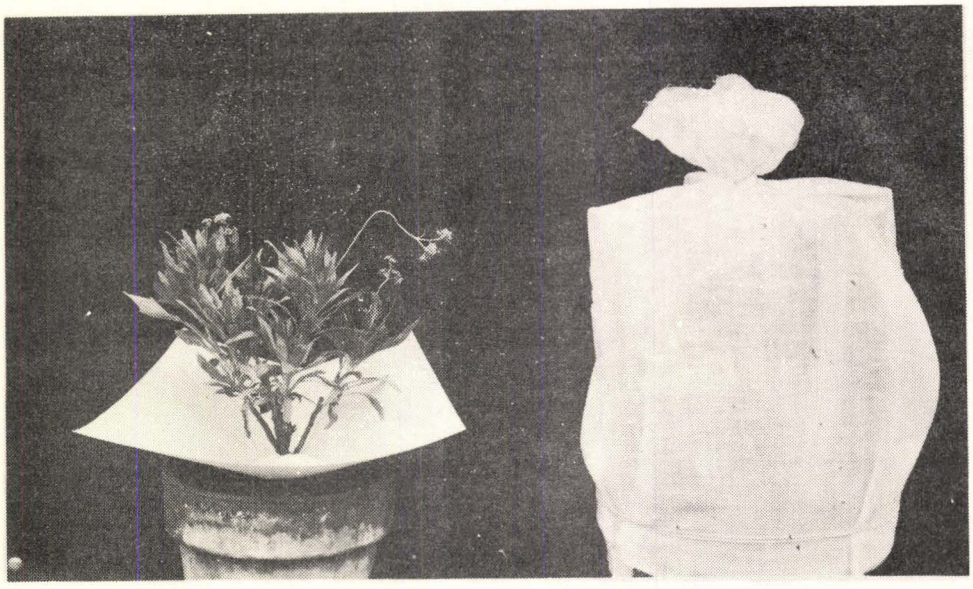

Figure 3.--Left, type of plant and collar used in experiments for control of red spiders and mealybugs on guayule; right, cage used to confine whiteflies and other insects on guayule after being sprayed with DDT emulsion.